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Steering Mechanisms for Knowability

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Abstract

The foundations of knowledge by tradition have been treated analytically and knowledge has been characterized as a theoretical subject. This article introduces a steering mechanism as the prerequisite for a study of knowledge work and maintenance on empirical grounds. Knowledge is treated synthetically, that is, as something that exists only through the individual's cooperation with its environment, which implies that criteria can be formulated for the isolation of knowledge processes. Specific processes may then be studied and interpreted with reference to manipulable factors and to the influence of these factors on measuring processes and theory construction.

Knowledge as Cooperative Process

The term " knowability " is likely to mean different things to different people. It may be conceived as belonging to the domains of formal science and as such be supposed to signal a fundamental meaning in some sense. To start a discussion of " steering " mechanisms with a term associated with problems of knowledge theory indicates that

1. acquisition and representation of knowing, and
2. knowledge diagnosis and maintenance

are conceived in computer age as central problems of psychology, calling for empirically founded solutions.

The orientation formed within the discipline of cognitive science concerns the development of knowledge models based on formal logics. A close reference to single computer programs as being realized models of representation plays an important part. Thereby cognition is conceived as synonymous with representation, which, in its turn, stands for an implementation of " intelligent behaviour ". The computer programs are, therefore, primarily studied as expressions of artificial intelligence.

However, in the focus of " Cognitive Science Research " are the study of how humans come to knowledge of their world, and how a systematic and at the same time multivariate theory may be developed and defined by the aid of computers. Here, a difference is made between classification (the basis of the artificial intelligence) and categorization, which means distinction, diagnosis, and identification. To become precise, this line of study is dependent upon the detection of transformation. Intelligent behaviour is observed as abstractions and the representation of abstractions, which motivates research on the computational constraints of knowledge processes. Cognitive Science Research, therefore, stresses the understanding of the meaning of analytically and synthetically oriented models respectively, and their consequences for both preservation and development of knowledge.

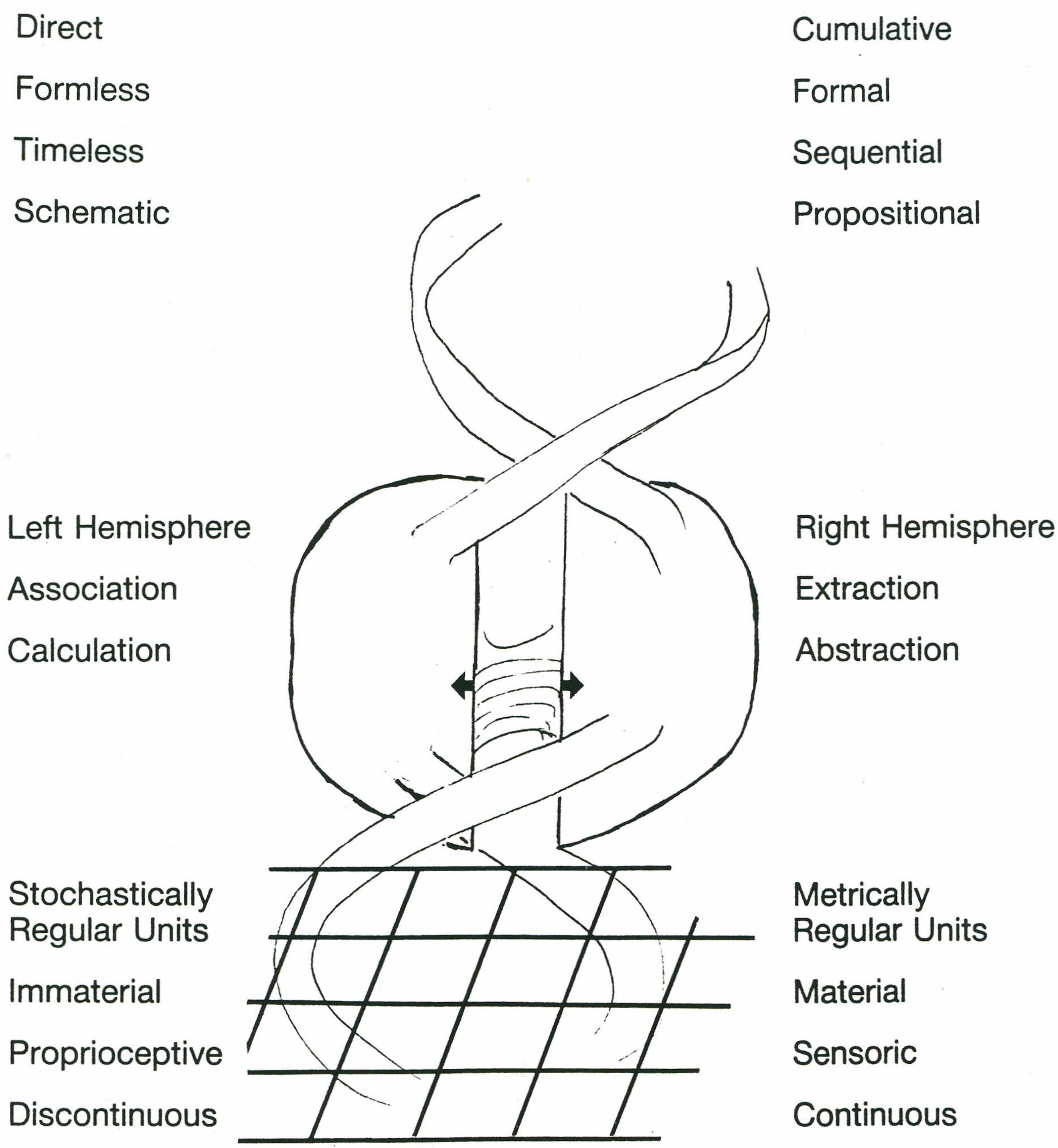
The research on communication processes between the two

brain hemispheres, which has attracted much attention in recent years, asserts that

1. the left hemisphere is responsible for analytical functions, whereas
2. the right hemisphere seems to stand for synthesis.

A modelling of intelligent behaviour in non-living systems with left or right orientation may give the steering components as presented in Figure 1. A result of the " split-brain " research is that the right hemisphere is uncapable of language and because of this cannot give verbal answers. Language is left-based, although the right hemisphere is capable of reaching a certain understanding of language and of spelling and writing. But more important is that language mediates information between the two hemispheres (⬅ ➡) (Harth, 1982, p 192), which motivates empirical studies of the function of language as cognitive instrument. The intertwined logics of the brain makes it very difficult to study the left-based language without considering the logic of the right side. It should be just as difficult to describe the functions of the right side without due consideration to the capability of verbalizing, typical of the left side. Since language incorporates both exterospecific and propriospecific information, it becomes important to investigate the function of language as link between cognition and intelligent behaviour.

The key to cultural and technical progress is to be found in the demand of natural language for self-reference in the representation of perception and experience. Typical of representation models developed in the traces of computer technology is the presupposition of knowledge being cumulative and hierarchic, which, moreover, reflects a commonly adopted belief. The deeply rooted idea about the cognitive mechanism is that knowledge is memory-based, which implies that the relation between different formulas (well-formed linguistic elements) can be computed. Knowledge can only be accessible when defined as a formal structure characterizing the total sum out of an addition of parts.



<u>Figure 1</u>. The two Hemispheres of the Brain in Cooperation

To study this process sensefully requires knowledge to be made explicit in terms of a set of propositions. Propositions constitute the formalism by the help of which knowledge is represented and probabilities for effective search are calculated. However, effective search presupposes an error-free memory (" database ") and well-defined knowledge domains (" homogenious problem domains "). To the extent that time or domain vary, they have been conceptualized as relations between successive states. Thereby the search methods can operate in the usual way. Time and domain relations exist only as far as " physical symbols " exist (Newell, 1981).

The hypothesis that a memory functions most effectively if it operates sequentially and syntactically is founded on the following assumptions:

1. All cognition implies calculation with a number of abstract elements.
2. The cognitive mechanism organizes and stores the abstract elements in networks.
3. Memory processes proceed linearly and the formal structure of the computation guarantees a priori correct and universal knowledge.

Memory as Cognitive Function

To document the " consolidation " of a memory has been a scientific goal since the turn of the century. Researchers interested in psycholinguistic problems have investigated the memory hypothesis in connection with language learning experiments (Müller & Pilzecker, 1900). It builds on the following assumptions:

1. A permanent storing capacity develops, which at the beginning of the process exists in a soft state.
2. A memory is consolidated over a certain time interval with clear-cut boundaries.

For this reason, memory research from the beginning concentrated on the final point of the memory process, that is, it has focussed upon time consumption, measured in seconds, hours,

and days.

The existence of the cognitive function was considered to be proved when the reaction time (RT) of an experimental subject (S) covaries with the sensation that different artificially created stimulus materials causes. The RT functions have proved to be independent of changes in the relative frequences of correct and wrong answers at the same time as they are approximately linear.

Since traditional memory research presupposes the world to be knowable only to the extent that it is computationally available, it has been frustrating that " errors " have occurred at both learning and retention as well as at recall. The formal structure of the computation, namely, is supposed to lead to a normative structure (as a result of the rules of logic). Therefore, the experimental efforts have aimed at developing procedures that would control the time lapse of the consolidation process.

The memory process is thought to develop according to the following three steps. It begins with an element- or batch-wise input of sensory data into a working area called " iconic memory ". This space is considered to have a high storing capacity but a very short retention time. Data are emptied very rapidly, counted in milli- or nanoseconds. In a next step, a smaller amount of this data set is represented in a somewhat more easily accessible form in something called primary memory or " short-term memory ", which calls for an explanation of the form of representation. Usually nodes and nets are assumed, binary states, and restricted storing capacity. From short-term memory is then transferred stimulus information to a library file or long-term memory for permanent storing. The storing of long-term memory is assumed to be rational as a result of its relation to formal logic, and connotative, since knowledge has to be augmented with meaning. Storing takes place in declarative form and both the storing capacity and the retention time are unrestricted. Under normal conditions, the symbol manipulation of the memo-

ry process is assumed to correspond to actions in the outer (real) world, which means that a logically founded cognitive mechanism can calculate what would happen, if one or the other action is performed.

A commonly accepted hypothesis for an experimental testing of the function of short-term memory is, for example, that certain particular formulas that the cognitive mechanism manipulates, like figures or letters, are organized in short-term memory as strings. The organization may differ concerning its logical set up but the short-term memory keeps a string just as long as necessary for the input of a number or word. The memory is emptied or the string erased by the input of the next string, that is, by interference with this string.

On the basis of this cognitive function hypothesis, Hebb (1961) was able to design a learning experiment and develop an experimental procedure which would test the hypothesis of the existence of a short-term memory. In short, the experiment aimed at letting S's learn long series of strings consisting of nine-figured numbers. Every third string was repeated. With this inbuilt repetition training Hebb could show that S's ability to " remember " the repeated information increased with increasing length of the series. Since the same effect could not be obtained for the non repeated strings, the short-term memory hypothesis must be considered doubtful. On the other hand, it is just as doubtful whether the RT function is appropriate for a testing of the memory hypothesis, since this function is sensitive to positional effects, to the relation between time pro recalled string, and to " space pro time unit " in the task of recalling a string. These effects occur most clearly when the strings are presented with a very short time of exposure and when the interval between the string from a series and the test string is short.

Melton (1963), therefore, designed a repetition experiment to control Hebb's results. Melton's experimental procedure tests the serial position of the strings, that is, the distances bet-

ween the repeated strings and their frequency of recurrence. Here, time is regarded as a continuous sequence of moments, which can be represented as elementary units and in a linear order for a calculation of constancy. Melton's results confirm Hebb's conclusions and, in addition, make possible to call in question the assumption of different mechanisms for a short-term and a long-term memory.

The Problem with the Memory Hypothesis

When the physical world is described through observable configurations of properties or with certain particular words, this is done in the formalism pertaining to logically constructed mechanisms. When the description concerns other things, it is, however, no longer an easy task to define a " memory ". Researchers have tried to prove its existence at several levels of analysis (Harth, 1982). If, for example, it is assumed that sensory input data are represented as points and through neurons and synapses, the explanation of the memory hypothesis is made according to a pulse logic similar to that of the computer. Efforts to prove that sensory information is mainly stored around the meeting points of the muscles means that memory is defined as a configuration of movements. Behaviour analysis, though, has shown that it is actions and not movements that are represented (Pribram, 1969).

The existence of an iconic memory is questioned by DiLollo (1980) among others, whose experimental results rather support the hypothesis of channels of parallel processing. Beverly and Regan (1973) give evidence of at least three different channels of this type. The experimental evidence reported indicates that information is processed with a high precision and that the channels are sensitive to both the direction of the movements and the distance to an object in motion.

The historical memory concept is based on the assumption of syntactic operations, which means that bits of information are associated to each other and stored as a copy of the world

in the brain. But Sperling (1963) doubts this assumption and states that information exists neither " visually " or " verbally " nor in any other form that can be made conscious.

Direct Perception of Information

There has to be a consciousness about the world before it can be knowable. The world is knowable to the extent that consciousness may be verbalized. The world knowledge that has been verbalized is explicit and communicable. That this is the case has been demonstrated experimentally (Gibson, 1979). Basic of the hypothesis of the direct perception of information is that the world is knowable through functions of higher order, which reflect ecologically significant aspects. Thus information is not represented as some constructed percepts, built up by appropriate association of elements randomly distributed in the perceptual field. Moreover, any information power to calculate is not assumed either. Instead, representation is a result of the organism's answer to ecological invariants. Perceptual (or cognitive) learning means a progressive differentiation. Piaget's research has given evidence that the child experiences a nearly undifferentiated totality, which means that it has not yet learnt to differentiate. It does not experience any continuous flow or sensory stimulation either, but only a whole world, characterized by the relations existing between the objects in its perceptual field. Gibson's experiment with a manipulation of information in such a way that it leads to illusions which cannot be differentiated from reality constitutes the counter-evidence of the idealistic assumptions of the classical memory hypothesis. In that a verbalization expresses ecological invariants and this process does not involve any loss of information (cf. sensory stimulation which reqires conservation) there is no need for a memory.

The meaning of an object or event can be detected, according to this hypothesis. This detection takes place before the observation of substances, surfaces, colours and contours.

Therefore, the world is knowable to the degree that it is specified in the structure depicting itself in some suitable medium. It follows that all cognition is based on the assumption that space and time exist only to the extent that they specify a relational order. Perception or conception of the environment rests on the ability to extract and abstract invariants. With this background, knowability may be defined as the synthesis of the individual's exploration.

Steering Components for Cognitive Science Research

Already at the beginning of computer age, von Neumann (1958) compared and contrasted the ways in which the brain and a logically constructed mechanism operate concerning cognitive functions. His conclusion was that the logic that steers thinking should be qualitatively different from the one steering the computer functions. The study of cognitive processes in the organism operationalized as calculation has been linked by cognitive science to humans' ability to perceive their environment (Becker), to communicate their perceptions (Winograd), and to come to knowing (Colby and Abelson). A computer simulation of thinking processes prerequires that psychological concepts have been defined. Moreover, it is required that the demonstrative definitions of the empirical research have been understood. Because, the understanding of reference factors of specific processes (manipulable factors) and the influence of these factors on the development of measuring processes and theory construction are crucial for a successful computer simulation, whereas programming is not.

Emergence of Self-reference

If we are able to see objects in motion as wholes, then this must be because of a synthesizing process. A study of such a process presupposes the development of an organism/formalism that makes possible a manipulation of both " intention " and " orientation ". The fundamental assumption underlying classical argumentation in philosophy and science is that natural lan-

guage is an insufficient instrument for the detection of the true nature of the world. For this reason, philosophers, logicians and mathematicians had to invent pure elements and relations between them. By manipulating symbols corresponding to the real world it would then be possible to determine, within a model world, what is true and what is false. In this way, formal logics would be a promising instrument in the description of natural language. Logicians and logically oriented linguists usually define language as a set of propositions. Propositions are structural definitions of a clause or part of one. A clause consists of a subject and a predicate linked (associated) through a copula, usually " is ". Intentions are conceptualized as the connotation of the proposition, that is, as instructions how to use a particular term. Orientation, on the contrary, takes place through denotation, which means that the term is used the way it is prescribed by established syntactic rules. In behavioural science terms, intention signifies a property of an organism acting purposely. Intention is connotated and the organism's behaviour (orientation) is expressed as denotated proposition.

The ability to synthesize the connotation of the proposition in the form of the predicate can be given the following expression:

$$\left\{ [\mathrm{int}\ (A)]\ a\ [\mathrm{ort}\ (O)] \right\} \qquad (1)$$

The first bracketed expression denotes that intention (int) operates, which is necessary in order for an organism (A) to be adaptive through cooperative actions (a). Any movement that may be ritualized such that it becomes an expression is seen as an indication of intention. Piaget's description of thumb-sucking is one example. The second bracketed expression indicates the importance of the ability to orient (ort) towards an Object(ive) (O). In the terms of Kant (1724–1804) we have an analytical pro-

position when the predicate is not contained in the subject. His proposition frequently cited

A triangle is a three-sided figure (2)

is analytical, according to this criterion, since the term " triangle " can be substituted with " a three-sided figure " each time they appear together. Kant declared that the connotations of the predicate which are contained in those of the subject lead to synthetic propositions. In behaviour science terms, this means that the world can only be understood with reference to synthesis. The smallest common denominator in this process is the relation between agent (A) and object(ive) (O) of its action, that is,agent and objective reside in the same organism.

The difficulty in keeping apart intention and orientation seems to depend on the fact that every meaningful behaviour intertwines them. An organism's cooperation with its environment requires the ability to express both in action. What a given environment means to a particular organism becomes obvious to it first after it has inquired into the consequences of its own behaviour.

In a famous research program carried out by von Frisch (1967), intention and orientation were used as experimental factors with the aim to study whether sounds and movements of bees carry such information that makes possible that the communication system of these insects could be called a language. The basic idea of von Frisch seems to have been that the action component (1) will differ concerning different intentional expressions and their meaning. The hypothesis that the intentional component represents a schema, reflecting a purpose that can be controlled by a manipulation of the orientation component, led to the following two measuring variables:

1. Variation of the organism through experimenting with artificially mixed colonies of bees.

2. Variation of the environment through changing the landscape and moving the colonies.

von Frisch could study the direct perception of information by means of a differential analysis of the way in which different colonies of bees communicated direction and distance to food places, which had been varied in different ways. A fixation of intention and orientation, on the other hand, may be regarded as a zero hypothesis, since, in this state, the organism is unable to lift the information from its carriers, that is, no wing-strokes - no intention to fly, and no food - no dance, which implies that no food places are sought out either.

What can be observed in this research approach is a systemic thinking, in which the properties of a bee being an autonomous observer of another bee is in focus. The initiator of this approach was Kant, who detected the importance of self-reference and who placed the autonomous observer in the centre of his philosophy. With this point of departure, a bee observing another bee picks up information about movements from what Gibson (1966) calls the optic array. This is perceived as a structure surrounding the observation point. The optical pattern available to an attentive bee specifies the movements the dancing bee has made. The geometric interpretation means that a body in motion is the moving point of observation, which generates a particular texture flow with its characteristic invariants (functions of higher order). With the description given, a bee communicates by transforming its knowing into abstractions. This means that the body is used to communicate integrated information within a discontinuous space — time system. It is further obvious that the dance of the bees specifies relations that remain invariant in the optical texture flow, implying that this flow contains structure. It follows that knowability can only be understood in the form of self-referring expressions.

The expression (1) thus carries the original information for an emerging structure and related cognitive processes. Both

structure and process can be modified by additional information provided from the environment. The structure embedded in expression (1) may be operationalized through a complementary arrangement of its components within a three-dimensional space. The anticipated process assumed to operate in this structure may be started or halted at any moment by fixating or mobilizing the action component (a), which is indicated with the (–, +) values. A fixation of both intention (–a) and orientation (–a) means no process, whereas a mobilization (+) means information synthesis. In this respect the relations (––, ++) are complementary to each other. If the world shall be known by von Frisch's bees, there has to be a medium, namely light, in which different dance patterns may depict themselves for making the available information detected. In the same way the (–+, +–) relations behave complementarily to each other. Through this double asymmetry each pair keeps a certain complementary control over every other. These symbols constitute the mechanism for a developmental control of differentiation and integration. When $\{a\ [\emptyset\ (A)]\}$ is bound to $\{a\ [\emptyset\ (O)]\}$ ($\emptyset$ = place holder) a cognitive development may be characterized as a change of the function of expression (1) and the process be characterized with two initial positions, in principle. This circumstance manifests itself as a change in the quality of the information.

The mechanism for differentiation and integration just described will now be used for transfiguration. By twisting and manipulating the measuring variables described and exemplified it will become possible to study the cooperation between environment and organism. According to Gibson, the " affordance " of the environment plays the important part for the organism's perception, which he defines as " invariant combinations of properties at the ecological level" (Gibson, 1979, p 127–140). With environment and organism as experimental factors a new set of interrelated components may be synthesized. When both components are fixed, that is, $\{-a\ [env\ (A)]\}$ and $\{-a\ [org\ (O)]\}$

perception of a stationary environment through a stationary eye is to hand. Many procedures within perception psychology have been developed to create this state with the purpose to calculate the power in the sensory stimulation. Stimulation above a certain value causes a response (effect) in the organism, so that the environmental information can be sensorily processed. But this does not imply perception, why this state characterizes the perceptual zero hypothesis. First through a manipulation of environment and organism so that variations in exterospecific and propriospecific information respectively can be measured it will become possible to study perception processes and the development of meaning. Since, according to Gibson, all information has these two specification poles, it is impossible to measure regularities in changes without reference to a particular organism. The mechanism founded on the expression (1) differentiates between the following two measuring variables:

1. Variation of exterospecific information through experimenting with viewpoints.
2. Variation of propriospecific information through changing the perspective or using different perspectives.

In this phase, the process has created two new differentiations and two new integrations. The ability to pick up information directly from changes in viewpoints and perspective means that the organism abstracts informative invariants and synthesizes what the environment offers to it, that is, what comes into view. Since this information synthesis is decisive for survival, the information must be intentionally utilized. To study perception as a cognitive process means that we may leave the " thing perspective ", which is a too concrete way of regarding stimuli.

This process creates at every twist and manipulation of the measuring variables accessible in a given phase two new differentiations and integrations. In letting this process operate we would realize that the development of knowledge cannot be discussed without reference to the intertwined cooperation

between structure and form. A developmental perspective on knowledge involves research on the cyclic course of the emergence of (1) invariance, (2) meaning, (3) understanding, (4) knowing, and (5) information. The development of a systematic theory of intellectual processes necessitates that implications of the use of these basic concepts in both factual and formal sciences are made visible.

The leading idea behind " Cognitive Science Research " is to discuss, with living systems as basis, fundamental principles underlying the construction of models for representing such systems and to contrast these with models aimed at representing non-living systems. A task of special concern then will be to choose those research approaches from the respective research tradition that may be analyzed and discussed differentially, so as to make clear the divergence in their conception of, for example, " meaning ". With point of departure in a description of living systems, form-based models seem to be insufficient for describing a cyclic development of knowledge. On the other hand, descriptions that do not purify the form may seem to obscure or to unduly confuse theories that are usually not looked on as connected to each other. However, there seems to be no other way to go, if we want to avoid taking the short cut over common sense psychology in our wish to demonstrate immediate and practically useful results.

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